METEOROLOGY.

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Introduction.

Meteorology, as usually defined, is the science of the earth's atmosphere. It embraces, therefore, both climate and weather.

Climate is concerned with statistics and deals with the normal or average state of such elements as pressure, temperature, humidity, cloudiness, precipitation, sunshine, fog, storminess, visibility and wind. A proper appraisal of the climate of a place or region must be based upon data covering a period of many years. The greater the length of this period, the more accurate will the appraisal be.

The state of these same elements at a given time and place, or during a particular period and in a specified region, is what constitutes weather. It can and does vary from a state of calm serenity to one of utmost peril to life and property.

Meteorology may also be considered from the viewpoint of theory and practice. In the former the various phenomena of the atmosphere that are our daily companions are studied in an effort to get at the underlying laws governing our weather and its changes. Although the interest here results in part from a desire to increase the sum of human knowledge, the chief purpose is to make more effective its practical application. Today applied meteorology is definitely and actively associated with all lines of industrial and commercial activity, and thus we have such subdivisions as agricultural, horticultural, insurance, marine and aeronautical meteorology. All of these are comparatively new, but perhaps the most recent is that branch which serves aeronautics. Certainly its development, in the past two years at least, has been more spectacular and on a much larger scale than has that of any of the others.

Aeronautical meteorology, like the more general subject meteorology itself, deals with statistics, or climate, and with current service, or weather. Aeronautics has very definite relationships with both. Let us see what some of them are.

I. STATISTICS, OR CLIMATE.

Statistical information may for our present purpose be divided into two classes: (A) that needed in developing the ground organization; and (B) that useful in determining regular flight schedules.

A. Ground organization. For the ground organization there should be included such climatological factors as frequency of different wind directions at the surface; average velocity of surface winds, classified by direction; frequency of strong surface winds, also classified by direction;

and frequency of gusty winds, poor visibility, fog, haze, smoke, heavy precipitation, etc.

As a rule there can be no great latitude in the location of airports, since these will necessarily be near the larger centers of population, and must be within reasonably easy reach of them. Little if any use can therefore be made of information concerning certain other climatological factors such as the frequency and intensity of thunderstorms, violent storms and temperature extremes, since in a small area their variation would be unimportant.

On the other hand there is in many cases, within comparatively small areas, considerable variation in wind conditions and especially in visibility. Gustiness is greatly increased by topographic irregularities, buildings and trees. A site as nearly free from these as possible should be selected. Information as to frequency of different directions and velocities of surface winds is important in connection with the orientation of hangers and the layout of runways.

But by far the most important factor to be considered in selecting an airport site is visibility. The relative prevalence of haze and smoke, particularly the latter, is a function of the prevailing wind. In general the selection of a site on the leeward side of a city should be avoided, other things being equal. However, primary consideration should be given to the occurrence of fog, - the one condition that reduces the visibility to zero. Mr. C. G. Andrus has the following to say on this subject, based upon experience as meteorologist at Hadley Airport since shortly after the passage of the air Commerce Act of 1926:

> "Fog frequency may be the deciding factor between airport locations otherwise equal. There is every reason to expect that the hazard attendance upon endeavors to enter an airport enveloped in fog will be only slightly minimized in the next few years. Only in necessity will it be done, and with passenger cargoes will be almost a prohibited maneuver. A dense fog 200 feet deep completely nullifies the utility of an airport as a terminal of entrance. Departure may be taken under such conditions if the airway to be travelled is clear of fog and the airport properly equipped, but even this is attended with considerable danger."

Fog frequency varies decidedly, in many cases, within small areas. Particularly is this true along the coasts of the Great Lakes and the oceans and in the neighborhood of rivers and small lakes. In general, all low-lying areas should be avoided, so far as possible.

In addition to wind and visibility, some attention should be given to the precipitation characteristics of a place. If heavy rains are frequent, the airport must be properly graded and drained. And if heavy snowfalls are to be expected, provision must be made for quickly clearing the runways. It is true that rain and snow do not vary much in amount within a small area, but some parts of such an area would in many cases be better than others for resisting the erosive or softening effects of

excessive rainfall and for quick clearing of heavy snow.

In the case of airports for the larger cities sufficient data are already available, as a rule, in the records that have been compiled at the local Weather Bureau offices. In some instances, however, it has been advisable to make what may be called a local meteorological survey. Several of these have been made and others are now being carried on. Perhaps the most complete is the one for San Francisco which covered one year and was conducted by that city in cooperation with the Federal Weather Bureau. Elaborate equipment was installed at several proposed sites and observations were made in great detail, of fog frequency, ceiling, visibility, gustiness and other meteorological elements. It is significant that the final selection of the San Francisco Municipal Airport was based solely upon the findings of this survey.

For the smaller cities and towns the problem is less difficult as a rule, the chief purpose, in many instances at least, being to provide intermediate landing fields on the major airways that will be available for emergency use. However, information concerning the average conditions at these smaller airports is needed and has been supplied and compiled by the Weather Bureau as part of a series of individual airway bulletins, published by the Department of Commerce. The meteorological data include a wind rose and a brief summary concerning strong winds, fog and heavy precipitation.

There has also been published a series of 48 bulletins, giving in more general terms the climatic characteristics of the several States. These contain sections on cloudiness, fogs, visibility, heavy rain and snow, ice in lakes and rivers, thunderstorms, surface winds, including frequency of strong winds, and upper air winds.

B. Schedule maintenance. Climatological factors useful in determining the most efficient flight schedules include resultant winds at flying levels; frequency of different wind velocities at flying levels, classified by direction; frequency of widespread storms; frequency and intensity of thunderstorms; frequency of low clouds and fog; visibility; and general character of precipitation.

In determining flight schedules for any proposed airway the most important datum is, of course, the cruising speed of the aircraft employed. To this must be added, or from it deducted, the resultant wind at different points along the route. This corrected value forms the proper starting point or basic datum for determining schedules. The operator of any service must decide what percentage of arrivals on time he will undertake to guarantee. It is then a comparatively easy matter to compute the schedules that, on the average, can meet this guarantee. The principal determining factor is the frequency of head and cross winds of various velocities, resolved into components parallel and perpendicular to the course. In general a considerably faster schedule can be adopted in this country for eastward than for westward flights, since, as is well known, the upper winds are prevailingly from the west. Moreover, the upper winds in general increase in velocity with altitude; therefore eastward flights should be at a higher level than westward flights.

Allowance should be made for a certain percentage of cancelled flights. This percentage will vary in different parts of the country and will also have a marked seasonal variation. It can be determined quite closely by an analysis of such climatological data as the frequency of widespread storms, low clouds, fog, poor visibility and heavy precipitation, especially snow. These conditions not only cause delays but occasionally prevent flights altogether.

Sufficient data are now available for studies of the sort above referred to. These data include upper air conditions, a branch of the subject that may very properly be called "aeronautical climatology". Already, practicable schedules for various cruising speeds have been determined for two of the airways, based upon a guarantee of 90 per cent arrivals on time. Similar analyses are being made for others of the major airways.

II. CURRENT SERVICE, OR WEATHER.

Statistical information has its place in aeronautics, and a very important one, as has already been seen. Yet, in a very real sense, it may be said to be only preliminary to the chief service that meteorology can render, namely, furnishing up-to-the-minute weather reports and forecasts for each and every flight. Nothing short of this will do. The experience of the past two years is conclusive.

In order to gain public confidence and support and to demonstrate its right to a prominent place in the industrial and commercial life of the world, flying must be both safe and efficient. Many factors enter in, including design and construction of aircraft, facilities at airports, marking and lighting of airways, instruction of pilots, licensing of aircraft, and adequate weather service. Some of these are chiefly concerned with safety, others with efficiency.

A. Safety. Until comparatively recently weather was generally thought to be responsible for quite a large percentage of aircraft accidents. This is no longer true. Weather service has already been developed to the point where accidents from weather rarely occur, if the warnings are heeded. It is significant that, in Report No. 308, "Aircraft Accidents" issued by the National Advisory Committee for Aeronautics, weather as a cause of accidents occupies an inconspicuous place in the "miscellaneous" section. It is of interest also to note that in an analysis of accidents published in the 1928 Aircraft Year Book by the Aeronautic Chamber of Commerce of America, Inc., only 12 out of 200 accidents and only 9 out of 164 fatalities were caused by weather. Of course even this number is too high and must be reduced, but the fact remains that weather is now one of the minor causes of accidents.

B. Efficiency. The case is entirely different when we come to efficiency. Here the weather service is the controlling factor. It determines whether the flying along an airway will be of the haphazard, hit-or-miss variety or of the type that takes advantage, in unfavorable weather, of every brief break or opening that woule enable a pilot to get through. Accuracy and promptness are the main essentials of such a service. Let us see what kind of an organization can best provide them.

1. Accuracy. In the first place there must of course be a system of regular weather reports at least twice, preferably four times, a day from a large area. This system of reports is fundamental, and all civilized countries have it for their own areas and usually for portions of adjoining countries and oceans. The reports are based upon observations made by trained personnel, with standard instrumental equipment and include upper air as well as surface conditions. They are collected at certain central points, and weather maps, bulletins and forecasts are issued.

The next requirement is a system of supplementary reports for comparatively small areas, each area covering a section of an airway. As yet it is difficult to say how frequent these reports should be, but it is significant that those who have had most experience in this work strongly advocate at least two-hourly and preferably hourly reports. If at two or three hourly intervals, they should include not only places on the airway itself but also a few selected points at some distance from and on both sides of it. These enable the meteorologist to watch the development and movement of adverse conditions approaching the airway from either side. If the reports are made once each hour, they may be limited to points on the airway itself, except that every second or third one should include also those at some distance from it.

These intermediate reports are based upon observations made by properly instructed, though not technically trained, personnel and with a set of instruments for indicating only the more important elements. The reports are accurate, but not of the high precision required in the general system for the whole country, and they include only information that is really needed, such as the state of the weather, ceiling, visibility, wind direction and velocity, temperature, pressure and a statement of any unfavorable condition, such as a thunderstorm, deep snow on ground, etc.

2. Promptness. So much for the character of the data or to express it in another way, the accuracy of the service. No matter how accurate, the service will fall down unless it is also prompt. Promptness requires: (a), an adequate system of communications; (b), close contact between meteorologist and pilot.

a. Communications. Communications may be called the "back bone" of the service. It is not for the meteorologist to say what system is best, but he is sure of one thing, namely that, whatever system is adopted, it must be under absolute control. The solution appears to be the joint employment of two or more different systems. Just now much attention is being given to the typewriter-printer for ground communication. This is supplemented by radio for ground to plane communication. Very likely other and perhaps better means will be devised in the future. Final selection will depend upon which system is most prompt, most dependable and smoothest in operation. But, as before said, this is not a problem for the meteorologi to solve.

b. Contact. The other requirement for prompt service, however, that of close contact with the pilot, is one that he himself, that is, the meteorologist, must provide. The telephone, or any other "distant control"

arrangement, will not answer in this case. Experience is conclusive, to the extent in fact that assignment of competent meteorologists at the more important airports is now the established policy of the Government.

Before each flight the pilot wants answers to the following questions:

1. What is the weather now at the terminal?
2. What is the weather now along the route?
3. Will there be any change during the next one to four hours (this period depending upon the length of the flight) and, if so, what kind of a change?

Answers to the first two questions are provided by a fast and dependable system of communication. Answer to the third is given by the trained meteorologist at the airport, where he can see and study the reports "hot off the wire", make his forecasts and talk the situation over with the pilot. Thus promptness and accuracy are combined in a service that results in a minimum of delay and cancelled flights.

The service is still incomplete, however, There are and will always be, at least for a long time to come, many occasions when the weather outlook is decidedly uncertain even to the best trained meteorologist. And this is where the value of a ground to plane communications system is shown. The pilot starts out with good weather prevailing and expected, but a fog suddenly develops at his terminal. A radio message tells him so and instructs him to turn back or land at the nearest field to his destination. Thus, within the limits of human endeavor, flying is made safe as well as efficient.

The service that we have briefly outlined is not in existence today on anything like a large scale. It is being tried out here and there in an experimental way. But it forms the goal toward which the Government is working as rapidly as it can. We hope and believe that the day is near when it will be functioning on every major airway in the country.